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The Influence of Silvicultural Practices On The Susceptibility and Vulnerability Of Northern Rocky Mountain Forests To The Western Spruce Budworm

COMPREHENSIVE PROGRESS REPORT
APRIL 1, 1982 - DECEMBER 31, 1982

Prepared December 31, 1982

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COMPREHENSIVE PROGRESS REPORT

For the Period April 1, 1982-December 31, 1982
by
Clinton E. Carlson, Leon Theroux, and Ward McCaughey

1. TITLE: The Influence of Silvicultural Practices on the Susceptibility and Vulnerability of Northern Rocky Mountain Forests to the Western Spruce Budworm

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c. Dr. David G. Fellin, Research Entomologist
d. Dr. Wyman Schmidt, Research Forester

4. ACTIVITY NUMBERS TO WHICH WORK IS ADDRESSED:

a. 2.2.1 Determine relationships of site/stand characteristics and management practices to stand susceptibility and vulnerability.

b. 2.3.1 Refine and improve stand projection model to include major budworm host types, with and without outbreak histories.

c. 3.1.1 Determine how and to what extent WSBW damage affects forest resources and management plans.

APPROVED BY:

Dave Fellin — 7 Dec 1982
DR. DAVID G. FELLIN, WSBW Team Leader — Date

Wyman C. Schmidt — 12/8/82
DR. WYMAN C. SCHMIDT, Project Leader — Date

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SUMMARY

Thirty-one stands were sampled in the Douglas-fir and subalpine fir forest climax series east of the Continental Divide in Montana and all seven previously established intensive sites were resampled. All data have been keypunched, entered into our Perkin-Elmer Computer system, and are now being edited and corrected.

An exploratory study on whether birds and ants affect WSBW larvae on small trees was conducted in two seed tree cuts. Ants were particularly effective and birds were to a lesser extent in reducing budworm numbers.

A major literature review showed that past insecticidal applications to reduce WSBW problems in the Northern Rocky Mountains have not been particularly effective. Silvicultural options may afford long-range protection to managed stands.

Analysis of all data collected since 1979 is being done and should be completed by July 1983.

Presentations of data were made at the Western International Forest Insect Work Conference in Missoula, Montana, during March 2-4, 1982; at the Northwest Scientific Association annual meeting in Walla Walla, Washington, during March 17 and 19, 1982; and at the Mission-Oriented Research Program Symposium, University of Montana, Missoula, in May 1982.

ACKNOWLEDGMENTS

This study was partially funded by the CANUSA-Budworms Program West. We thank Dr. David G. Fellin and Dr. Wyman Schmidt for their continued support of this research. Special appreciation is given to Jerry McCarthy, Paul Hengel, Randy Kerr, Julie Huber, and Donna Hintz for their persistence, patience, and dedication to completing the fieldwork, often under adverse weather conditions. We extend our gratitude to Marilyn Harris for typing the manuscript and for being critically aware of inconsistencies in the paper. Finally, special thanks are given to Bryan Owen for his excellent talents in illustrating the cover and text figures.

INTRODUCTION

It has been suggested that silvicultural strategies can be employed to reduce tree damage caused by the western spruce budworm, Choristoneura occidentalis Freeman. With this concept in mind, this 5-year study was designed to:

1. Identify silvicultural strategies that will minimize the impact of WSBW (western spruce budworm) on conifer regeneration in managed forests of the Northern Rockies;

2. Provide a quantitative data base with which to make critical decisions about WSBW damage to regeneration; and

3. Improve the state-of-knowledge of the complex interactions between WSBW, site and stand conditions, environmental gradients, vegetation types, and other biotic and abiotic factors.

This comprehensive report details the progress made during April 1, 1982-November 15, 1982, and specifically relates to the research proposal to CANUSA West, "The Influence of Silvicultural Practices on the Susceptibility and Vulnerability of Northern Rocky Mountain Forests to the Western Spruce Budworm," by Clinton E. Carlson, submitted in September 1981. Objectives for this period were:

1. Measure the effect of WSBW on height growth, vigor, and crown development of established conifer reproduction between ages 5 and 15 years in various harvest systems in the Douglas-fir and subalpine fir forest climax series of eastern Montana; and

2. Determine if past WSBW activity has adversely affected the establishment and growth of conifer regeneration relative to various silvicultural systems.

METHODS AND DESIGN

Selection of Stands

Data were collected from conifer stands between 5 and 15 years old which resulted from previous harvest cuts in the budworm-susceptible Douglas-fir and subalpine fir forest climax series present in eastern Montana (fig. 1). Four regeneration cutting systems (clearcut, shelterwood, seed tree, and selection) were studied relative to two levels of budworm infestation (none-to-light and moderate-to-heavy). Units of three sizes were selected (<5 acres, 5-50 acres, and >50 acres), and two replicates were considered. It is stands of these types that the land manager--be he federal, state, or private--is very interested in from a silvicultural perspective relative to the effect of budworm. Thus, the design implies that 48 stands would be selected and studied in 1982 (one series x two budworm levels x four cutting systems x three unit sizes x two replicates).

Listings of candidate stands were obtained from Forest Service Region 1. Candidate stands were selected on the Gallatin, Helena, and Lewis and Clark National Forests, all located east of the Continental Divide in Montana.

Stands selected for study must have met the silvicultural standards prescribed at time of cutting. We did not want to sample stands that were hygraded, leaving only the poorest material for seed source. Rather, for example, in seed tree cuts, we selected stands in which average or better trees were left for the seed source and reasonably good site preparation was attempted. Potential study sites were selected at random and field checked to assure that our basic criteria were met.

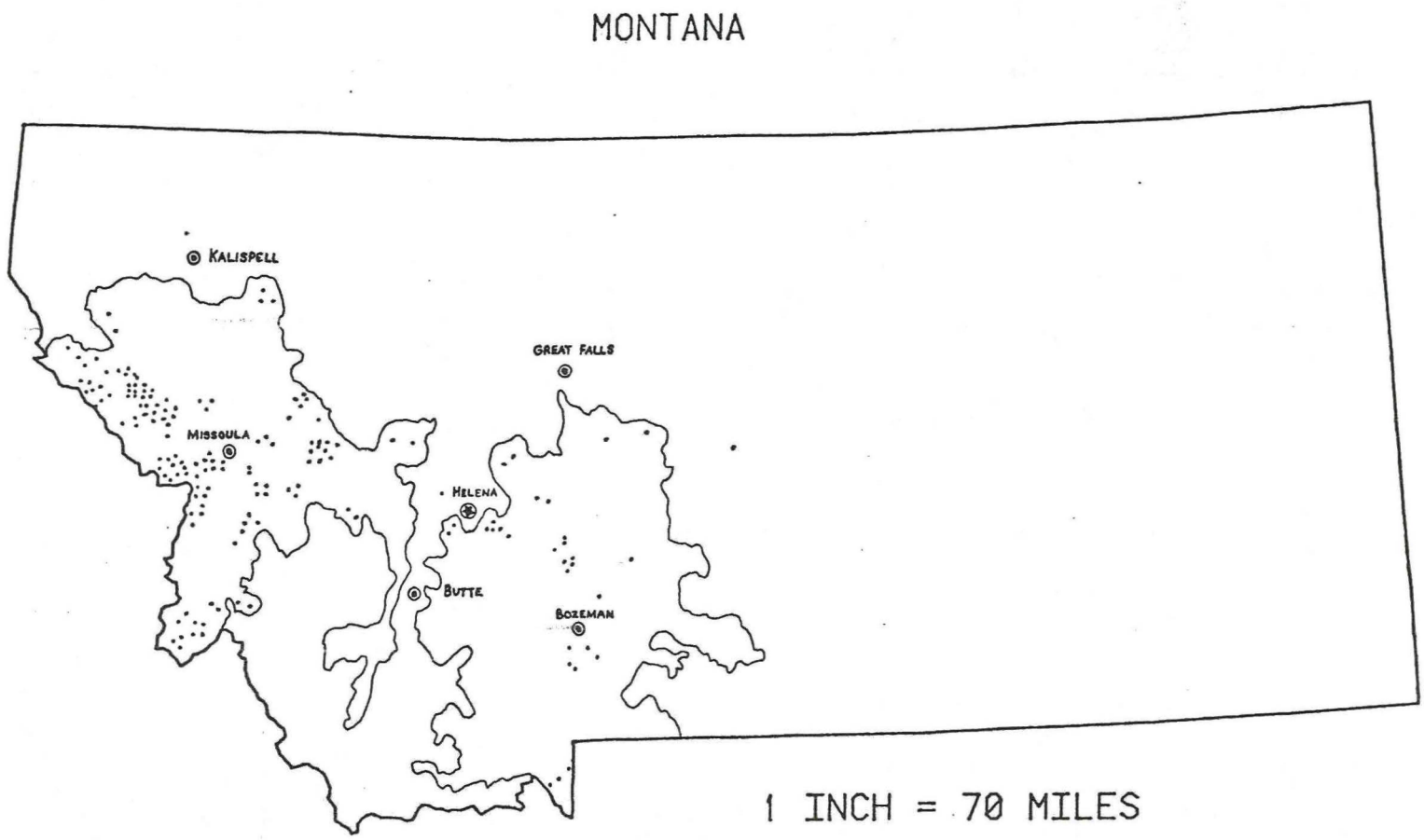

Figure 1.--These are the relative locations of 166 stands sampled between 1979 and 1982. The stands are a random representation of clearcut, seed tree, shelterwood, and selection harvest cuts located in the Northern Rocky Mountains of Montana. WSBW can be found at each stand but varies in intensity from light to heavy. The solid lines exclusive of the state boundary indicate the general extent of past WSBW activity.

Field Sampling

ADJACENT STANDS

The residual stand adjacent to the selected study stand was characterized. About five to seven variable-radius plots were established, and species composition, basal area, crown classes, crown ratios, heights, and diameters were recorded. All WSBW host trees within the variable plot were rated for defoliation, using the three-crown strata system agreed upon at the Lubrecht meeting.[1] The live crown is visually separated into lower, middle, and upper thirds. Each portion is then rated for WSBW defoliation and coded as follows:

Description	Code
No defoliation	0
Light defoliation	1
Moderate defoliation	2
Severe defoliation	3

These are subjective classes and reflect defoliation over a period of years--1 to 7 or 8--depending on the situation.

It is important that the history of WSBW in these adjacent stands be known. We assume that if WSBW had been intense enough to have caused a detrimental effect in the study stands, it also would have been adequately intense to have caused an observable effect on radial stem growth of residual host trees in the adjacent stands. We have collected and analyzed preliminary data that indicate, indeed, that this is the case (Carlson and McCaughey 1982). Therefore, from all study stands two increment cores from each of three defoliated host trees and three nonhost trees were extracted, placed in plastic straws to prevent dehydration, and transferred to our laboratory where annual radial increment was measured, recorded, and analyzed.

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[1]CANUSA meeting held at Lubrecht Experimental Forest in western Montana, May 16, 1979.

SAMPLING WITHIN CUTTING UNITS

Plots 1/300 acre in size were established along parallel transects that encounter most of the recognized site variability. Stage (1973) used plots of this size in similar studies and found them adequate, and National Forest management routinely uses 1/300-acre plots in silvicultural examinations. Sampling error for a given variable within a matrix cell[2] should be within the confidence interval:

$$\bar{x} \pm T_{.05} (SE_{\bar{x}}), \text{ such that:}$$

$$\frac{T_{.05} (SE_{\bar{x}})}{\bar{x}} \leq .20$$

A number of variables known to influence conifer regeneration establishment, survival, and growth were measured at each plot. It is important that this study relate to and be understood by forest land managers. Therefore, many of the variables measured within each stand and plot are those variables routinely measured in stand examinations by foresters and silviculturists.[3]

Each plot was unique as the sampling unit and all variables were quantified. Thus, the stand selection criteria were quantified and recorded as follows:

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[2]A matrix cell is defined as any single combination of the stand selection criteria.

[3]See "Field Instructions, Stand Examination and Forest Inventory." Stand Examination Handbook FSH 2409.21, R1, Chapter 300. April 1978. USDA, Northern Region. 113 p.

a. Forest climax series - habitat type

b. Budworm damage rating given to residual stand (Bousfield[4]) and increment analysis as described above

c. Cutting system - Basal area of residual stand was estimated with a 10 BAF prism

d. Cutting unit size - acres

Intrinsic site variables measured and recorded at each plot were:

a. Aspect; degrees

b. Slope percent

c. Physiography; ridgetop, dry slope, moist slope, stream bottom, flat or bench

d. Site preparation - none, mechanical or burned

e. Relative position of suspected seed and WSBW source by bearing, distance, and angle from plot center.

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[4]The actual method was determined at a joint field meeting of the Moscow and Missoula INT Laboratories. Personal communication with Wayne Bousfield, FPM, Region 1 Forest Service, Missoula, MT.

It is standard practice in National Forest management to consider the dominant two established seedlings on each 1/300-acre plot as "management trees," or those seedlings most likely to become the preferred crop trees. Therefore, the following data, known to be silviculturally important, were collected from the two tallest established trees on each plot and recorded:[5]

a. Height from ground line to the bud scar of the previous year, in 0.1 foot
b. Species
c. Age - sample trees were cut at ground line and annual rings tallied
d. Dead or alive
e. Established or nonestablished
f. Vigor - height growth during past 5 years, 0.1 foot
g. Advanced growth or subsequent
h. Planted or natural
i. Crown position
j. Crown width, 0.1 foot
k. Crown length, 0.1 foot
ℓ. D.b.h., inches
m. Growth of current year - 0.1 foot

It was also important to assess the relationship of budworm to nonmanagement trees, or those seedlings that would not be carried through a rotation. Does WSBW preferentially damage intermediate crown classes or the dominants, or is there no difference? Therefore, all established conifer seedlings, other than the two tallest, were tallied, and the following information was recorded:

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[5]Details of these measured variables are presented in our 1981 continuing research proposal to CANUSA West, "The Influence of Silvicultural Practices on the Susceptibility and Vulnerability of Northern Rocky Mountain Forests to the Western Spruce Budworm."

a. Species
b. Crown position
c. Height to nearest 0.1 foot
d. Growth of current year - 0.1 foot

The incidence of budworm defoliation on regeneration is an indication of the relative influence of silvicultural system on budworm susceptibility and vulnerability of management and nonmanagement regeneration. Damage data provide direct evidence of the feeding preference of budworm and the responses of seedlings to budworm pressure. Budworm feeds differently on western larch than on other conifer hosts; therefore, assessment techniques differ. The following sampling methods developed and tested in 1978-79 were utilized to assess current WSBW damage on host seedlings.

a. Douglas-fir, grand fir, subalpine fir, and Engelmann spruce--tallest (management seedlings)

The crowns were visually separated into three equal parts: upper, middle, and lower. A maximum of six shoots within each crown level were evaluated for current and previous WSBW defoliation and rated as follows:

Percent Defoliation	Code
0	0
1-25	1
26-50	2
51-75	3
76-99	4
100	5

Shoots were selected about equally around the crown, and percent defoliation was recorded for both current and previous years. Data for each shoot were recorded. A mean index and proportion damaged were then computed and recorded for each tree.

b. Western larch management seedlings

Fascicular damage. Each tree crown was visually separated into three portions. Within each portion, 33 dwarf shoots (fascicles) were observed, and the number of fascicles with WSBW feeding evidence was recorded. An average for the tree was derived and entered.

Lateral shoots. Ten current-year lateral shoots from upper crown were examined and the number of shoots fitting each of the following criteria was recorded:

	Type of Damage	Code
a.	No damage	0
b.	Needle-feeding only	1
c.	External shoot-mining	2
d.	Severed shoots	3

In all cases, only the most severe type of damage was recorded.

Terminal leader. Damage to terminal leaders was recorded on Field Sheets 4 and 1, as follows:

	Type of Damage	Code
a.	No damage	0
b.	Needle-feeding only	1
c.	External shoot-mining	2
d.	Severed shoots	3

c. Excess seedlings (established and nonestablished), all host species

The entire seedling was subjectively rated for defoliation, coded, and recorded on Field Sheet 1, as follows:

Defoliation	Code
0	0
1-25%	1
26-50%	2
51-75%	3
76-99%	4
100%	5

It is recognized that agents other than budworm may be responsible for seedling damage; the following general damage codes were entered:

	Damage Agent	Code
a.	Budworm	0
b.	Weather	1
c.	Animal	2
d.	Other insect	3
e.	Disease	4
f.	Healthy	5

Intensive versus Extensive Sites

The major effort of this research was to visit and characterize as many different stands as possible within given funding restraints. Therefore, most stands were observed only once--they are the "extensive" stands. However, it was deemed to be of considerable interest to annually remeasure plots established in certain stands. These are termed the "intensive" sites. Data from these sites will be used to calibrate growth data from the extensive stands.[6]

[6]A more detailed description of the relationship of intensive to extensive sites is given in "Interim Report to CANUSA West" by C. E. Carlson, Jan. 1981.

By 1980, seven intensive sites had been selected and sampled. These sites were resampled in 1981 and 1982. Data were collected in exactly the same manner as for the extensive sites except that the management trees, because they were to be followed in future years, were not cut for aging. Instead, age was estimated by the number of branch whorls present.

Small Tree Study

In previous years we observed that early WSBW instars (2-4) were easily found on host regeneration in young managed stands. However, we seldom found any instar 5-6 larvae or pupae on small trees. In an attempt to determine the fate of WSBW larvae on small trees, we cooperated with Dr. Robert Campbell of the Pacific Northwest Forest and Range Experiment Station in an exploratory study. Eighty trees ca. 1 m high were selected in each of two seed tree cuts northeast of Missoula, Montana. Four treatments--control, exclude ants, exclude birds, exclude birds and ants--were randomly assigned to the experimental units (fig. 2, see appendix 1 for details). Total remaining WSBW (as larvae and pupae) and total defoliation were recorded at study termination.

Western Spruce Budworm Population Sampling

Estimates of WSBW larval populations and defoliation were made at 12 locations according to CANUSA West minimum standards. These locations were:

1. All intensive sites (7)
2. All study sites of Shearer and Tiernan[7] (4)
3. Lubrecht, a previous site selected by Dr. David Fellin.

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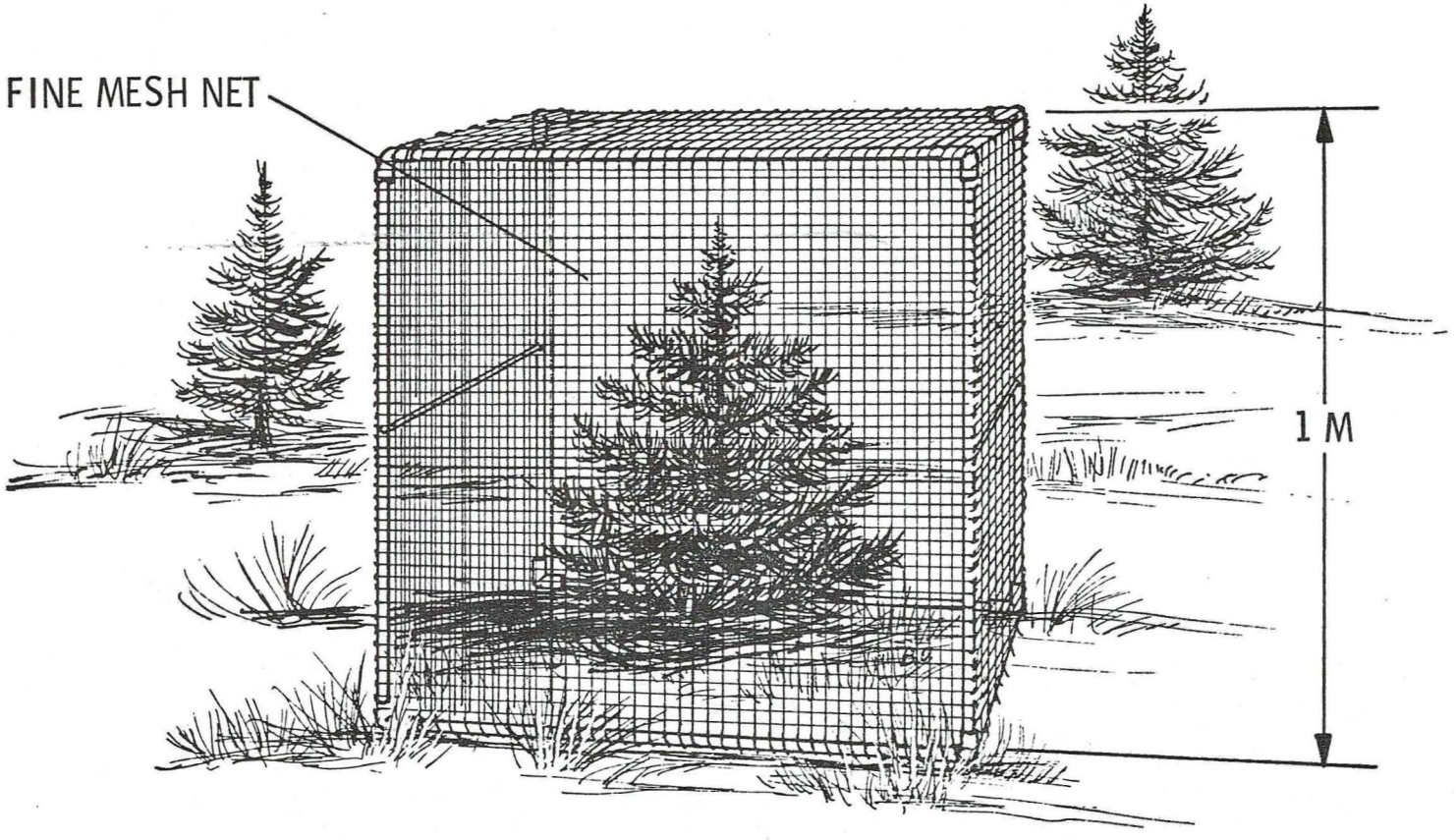
[7]R. C. Shearer and C. F. J. Tiernan. 1980. Assess effects of WSBW feeding and defoliation on cone and seed production within the Northern Rocky Mountains. Research Proposal to CANUSA West.

Figure 2.--Bird exclusion treatment for the exploratory study of bird and ant predation of WSBW on small trees. The cages were about 1 m on a side and were covered with 1 cm by 2 cm polypropylene netting. Other treatments were: exclude ants, exclude ants and birds, and control. Ants, and to a lesser extent birds, were effective in reducing larval populations on small trees in managed stands.



Collection sites are listed in table 1. The studies of Tiernan, Shearer, and Carlson were conducted under a team concept at the Forestry Sciences Laboratory in Missoula; the collection of larval and defoliation data for all studies was assigned to Carlson.

Table 1.--1982 sites for larval population and defoliation estimates

Intensive Sites

Unit number	Location name
126	Valley Creek #1
143	Blue Mountain
135	Chamberlain Creek
200	First Creek
205	Second Creek
210	Valley Creek #2
215	Union Peak

Fellin's Site

Unit number	Location name
147	Lubrecht

Cone and Seed Sites

Unit number	Location name
220	W. Fork Lolo Creek
107	Ashby Creek
116	Spring Creek
143	Blue Mountain

At each site, CANUSA minimum standards were followed:

1. Three plots previously established at each site and consisting of three tagged WSBW host trees of dominant or codominant status were resampled.

2. During early spring, when WSBW larvae were judged to be at Instar IV, four branches were cut from midcrown of each tree. The number of WSBW larvae per 100 buds was counted and recorded.

3. In late fall, when all WSBW feeding had ceased for the season, defoliation was estimated. The crown of each tree was conceptually divided into thirds, and percent defoliation was estimated in 5-percent increments for current and past defoliation and recorded. Then four 70 cm branches were collected from midcrown of each tree and represented the four cardinal directions. Twenty-five current shoots from the apical 40 cm of each shoot were rated for defoliation as follows:

Defoliation Class	Code
0	0
1-25%	1
26-50%	2
51-75%	3
76-99%	4
100%	5

All data were entered into an electronic data file on our Perkin-Elmer Computer system.

Data Analysis

The null hypotheses being tested are:

1. WSBW does not influence conifer regeneration establishment
2. WSBW does not influence conifer regeneration growth
3. WSBW defoliation is not different on different species
4. Regeneration cutting system does not affect budworm activity
5. Unit size is not related to budworm damage on regeneration.

Simple and multiple regression and nonparametric techniques are being utilized to analyze the data. Independent variables include forest climax series, budworm infestation level, residual basal area, unit size, and distance to seed source. Dependent variables will include seedling density, probability of stocking, and damage. Covariates in the analysis include the intrinsic site variables such as slope, aspect, physiography, etc. Specific models are presented in RESULTS AND PROGRESS.

RESULTS AND PROGRESS

This continuing study was originally conceived to collect and analyze regeneration data from three forest series: Douglas-fir, subalpine fir, and grand fir. Data were collected from 48 stands in 1979, 48 in 1980, and 39 in 1981. In 1982--the final year of data collection--an additional 31 stands were studied. Thus, over the study period of 1979-1982 we have collected data from 166 stands (table 2). There are four main functional aspects to such a study once it is funded. They are:

1. Collect and record field data
2. Enter data on punch cards, establish computer files, correct and edit data
3. Analyze and interpret data
4. Publish and/or report results

These functional aspects overlap forest series in our study because each series was dealt with in a separate, successive year: Douglas-fir in 1979, subalpine fir in 1980, and grand fir in 1981. For data collected in a given year, it has taken us until late December to read the increment cores, keypunch all data, and establish the data files. Data analysis then is done during spring of the following year. Therefore, this progress report deals with analysis of data collected in 1979 from the Douglas-fir series, in 1980 from the subalpine fir series, and 1981 from the grand fir series, status of data collected in 1982 from the East-side stands, and preliminary results from the small tree study.

Table 2

STAND SUMMARY DATA FOR STANDS EXAMINED IN 1979

STAND	CUTSYS	ACRES	PLOTS	HABIT	ASPECT	SLOPE	PHY	PREP	SEVIDX	AGE	STOCK	ELEV	IBA	OBA
2	14	35	21	312	14	11	2	2	0.37	12	23	3700	70	110
5	14	200	23	313	3	1	5	1	0.00	10	6	4600	63	180
19	13	36	27	312	14	10	5	1	0.44	12	29	5400	6	90
20	13	56	37	261	16	43	3	1	0.71	15	54	5000	15	208
21	13	33	26	323	12	39	2	2	0.00	15	26	6500	12	68
23	11	5	11	313	28	52	2	1	0.00	15	27	5600	0	280
25	11	30	29	283	19	36	3	3	0.27	10	31	4900	0	124
26	11	29	32	521	11	45	3	3	0.71	10	77	5100	0	88
31	11	4	9	313	28	43	3	2	0.42	14	55	5400	2	112
35	11	20	21	312	8	17	2	2	0.41	14	57	5100	2	84
41	11	5	11	323	17	37	2	2	0.00	18	18	6600	0	155
54	12	11	13	283	16	31	2	2	0.38	8	53	5700	26	130
66	12	65	24	210	19	53	2	1	0.76	12	75	4000	23	95
69	12	24	19	282	15	23	2	1	0.60	10	84	5200	21	64
70	12	55	30	321	21	31	2	1	0.31	13	20	6100	35	60
73	14	51	19	293	20	39	3	1	0.30	11	100	4300	23	50
74	12	166	35	311	16	34	2	1	0.50	12	40	5700	18	130
100	14	4	7	283	7	37	3	1	0.31	13	42	4900	54	35
102	14	4	8	262	25	61	2	1	0.20	5	37	4800	8	60
124	13	31	19	262	27	36	2	2	0.63	7	26	4800	13	20
126	14	30	33	262	9	21	2	1	0.43	8	51	3600	27	73
127	11	120	28	261	28	49	2	2	0.28	17	46	4600	2	106
128	12	37	22	261	5	39	2	1	0.86	8	50	4400	19	76
129	11	43	21	261	9	36	2	3	0.61	15	23	5400	0	90
130	13	81	34	283	22	13	2	1	0.00	9	52	5600	8	147
131	13	31	20	261	21	31	2	3	0.58	15	60	5000	8	83
132	14	49	25	283	20	14	2	1	0.00	11	36	5700	48	133
133	13	5	6	283	29	11	2	1	0.38	9	33	5600	43	115
134	12	28	13	312	13	33	2	2	0.00	10	38	6500	23	105
135	13	186	55	312	15	22	2	1	0.59	6	32	3900	10	66
136	11	5	7	283	9	39	2	1	0.62	17	85	6200	6	93
137	11	2	6	262	22	55	2	1	0.53	13	83	4900	13	73
138	11	20	18	312	23	47	2	2	0.65	13	77	4900	4	132
139	12	4	7	322	26	45	2	1	0.49	13	100	5500	26	110
140	11	61	17	322	16	47	2	2	0.33	10	47	5200	1	56
141	12	7	13	311	26	46	2	1	0.67	5	76	5100	17	40
142	14	4	12	282	11	15	5	1	0.75	11	75	3600	50	50
143	11	80	46	261	18	58	2	1	0.00	18	52	4600	2	95
144	13	50	24	261	9	39	2	1	0.00	11	33	4800	11	72
145	14	50	17	261	21	42	2	1	0.65	9	5	5600	80	130
146	11	150	27	312	17	13	5	3	0.00	14	48	5300	1	120
148	14	67	23	262	17	23	2	1	0.67	10	21	4500	30	60
149	14	45	25	261	16	37	2	1	0.70	11	44	4900	15	68
150	14	5	6	261	11	31	3	1	0.55	8	33	4000	33	53
151	12	27	16	321	23	25	2	1	0.58	11	37	4300	31	30
152	14	23	20	262	25	20	2	1	0.45	13	45	4200	30	52
153	11	51	17	261	14	32	2	3	0.58	16	82	4500	0	77
154	13	5	11	261	8	35	2	1	0.51	6	9	4400	24	92

KEY:

CUTSYS = CUTTING SYSYEM

HABIT = HABITAT TYPE

ASPECT = ASPECT IN DEGREES

SLOPE = PERCENT SLOPE

PHY = PHYSIOGRAPHY

PREP = SITE PREPERATION

SEVIDX = SEVERITY INDEX

STOCK = PERCENT STOCKED

ELEV = ELEVATION

IBA = INSIDE BASAL AREA/ACRE

OBA = OUTSIDE BASAL AREA/ACRE

Table 2 (continued)

STAND SUMMARY DATA FOR STANDS EXAMINED IN 1980

STAND	CUTSYS	ACRES	PLOTS	HABIT	ASPECT	SLOPE	PHY	PREP	SEVIDX	AGE	STOCK	ELEV	IB.A	OBA
200	11	13	28	592	29	41	2	1	0.83	20	89	4100	4	64
205	12	20	25	591	4	27	3	1	0.81	20	92	3800	38	72
210	14	65	49	662	25	25	3	1	0.77	7	69	4600	59	82
215	13	30	41	691	4	39	3	1	0.00	9	65	5800	29	155
220	12	2	7	662	5	19	2	1	0.00	17	100	5400	39	65
221	14	25	16	692	11	32	3	1	0.00	13	65	5100	74	95
222	14	42	26	691	15	49	2	1	0.00	15	80	6000	23	98
223	12	4	12	691	11	24	2	1	0.00	7	100	5800	62	63
224	12	6	11	691	13	29	2	1	0.00	7	81	5600	42	125
225	12	16	18	720	12	26	2	1	0.00	8	77	5800	9	128
226	13	79	24	691	30	30	3	2	0.00	8	45	5900	3	82
227	12	4	8	670	1	48	3	1	0.62	18	100	5800	50	105
228	12	20	15	670	27	52	3	1	0.00	18	86	5800	52	65
229	11	31	25	670	12	45	2	3	0.62	13	80	5700	3	148
230	12	77	26	691	28	49	3	1	0.50	15	88	5300	57	97
231	11	12	14	691	25	38	2	3	0.00	14	57	7100	0	53
232	13	109	22	640	20	10	5	2	0.00	15	27	4500	2	80
233	13	38	14	691	24	19	3	3	0.00	14	85	5800	0	83
234	13	31	15	691	15	24	2	2	0.00	15	40	5600	7	63
235	11	4	6	625	34	59	3	3	0.00	20	100	5200	0	55
236	12	63	20	283	28	55	2	1	0.43	18	30	5300	18	48
237	12	4	7	625	2	31	3	1	0.38	16	28	5000	7	38
238	11	23	18	670	5	33	3	3	0.00	13	44	6200	0	93
239	12	67	25	691	14	28	2	2	0.00	11	56	6300	5	78
240	11	4	8	691	10	57	3	3	0.00	13	50	5000	4	75
241	11	32	20	670	29	42	3	1	0.00	14	95	5800	1	80
242	13	3	11	691	25	33	2	2	0.00	6	54	6200	7	103
243	12	8	14	691	13	27	2	1	0.65	7	64	5700	20	46
244	12	54	26	691	16	25	2	1	0.00	7	96	6100	22	98
245	13	3	10	640	29	25	3	1	0.65	18	100	4400	8	63
246	13	12	16	640	15	25	2	1	0.00	18	62	4200	10	60
247	14	56	26	691	9	49	2	1	0.76	20	100	5400	84	57
248	11	90	25	662	23	30	3	3	0.00	15	52	5000	0	92
249	14	12	13	670	9	35	3	1	0.23	14	92	5000	82	58
250	11	3	5	692	17	27	3	3	0.00	13	80	6200	0	75
251	11	4	8	691	16	45	2	3	0.00	9	0	6500	0	80
252	11	88	23	625	9	41	3	3	0.00	6	60	4800	0	68
253	13	80	22	624	11	11	3	3	0.75	6	63	4800	0	60
254	11	61	22	625	32	27	3	3	0.44	10	81	5400	0	48
255	13	69	21	691	20	17	2	2	0.00	13	47	5000	3	48
256	11	65	18	691	18	39	2	1	0.00	12	50	6200	0	108
257	14	16	9	670	10	57	3	1	0.51	18	100	6000	42	85
258	14	5	8	691	7	52	3	1	0.59	6	50	5500	11	93
259	11	76	25	691	23	41	3	3	0.00	13	76	6100	0	97
260	13	19	17	662	27	48	2	1	0.00	10	94	5800	25	53
261	14	14	12	691	9	48	2	1	0.00	19	83	5400	38	65
262	14	10	9	670	13	39	3	1	0.00	19	100	5400	50	63
263	11	4	8	691	24	41	3	3	0.49	16	0	6500	1	76

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Table 2 (continued)

STAND SUMMARY DATA FOR STANDS EXAMINED IN 1981

STAND	CUTSYS	ACRES	PLOTS	HABIT	ASPECT	SLOPE	PHY	PREP	SEVIDX	AGE	STOCK	ELEV	IBA	OBA
300	11	40	16	743	5	47	3	3	0.49	12	56	5500	0	105
301	14	12	14	523	19	24	3	2	0.34	11	78	4700	27	110
302	12	30	16	510	8	23	3	1	0.59	14	100	4600	44	76
303	14	25	14	263	10	11	3	2	0.61	5	42	6000	51	105
304	14	25	18	510	8	19	3	2	0.49	7	66	5300	35	75
305	11	80	27	591	26	42	3	3	0.00	11	51	5000	0	51
306	11	7	11	293	28	46	3	3	0.73	9	72	4500	0	88
307	11	4	9	262	9	51	3	2	0.49	9	88	4200	0	80
308	11	2	9	591	5	43	3	2	0.64	20	44	4100	0	100
309	11	40	47	531	16	38	3	3	0.53	16	61	4600	0	78
310	11	5	9	591	22	51	3	1	0.61	16	77	4800	0	100
311	11	79	35	591	25	46	3	3	0.62	18	61	4400	0	90
312	14	13	11	591	2	43	3	1	0.00	19	61	4800	50	108
313	11	3	8	521	14	47	3	3	0.00	19	75	4800	0	80
314	11	4	7	531	9	26	3	3	0.75	10	71	4600	0	78
315	13	18	15	621	9	38	3	2	0.49	6	46	5200	41	116
316	11	8	12	522	24	50	3	3	0.87	10	66	4300	0	115
317	11	68	30	510	2	3	5	3	0.60	14	66	3200	0	86
318	11	25	16	522	20	45	3	3	0.63	14	75	4500	0	94
319	14	5	9	510	4	50	3	1	0.47	6	60	4900	32	75
320	12	7	10	510	2	42	3	1	0.52	6	50	4800	33	158
321	13	23	17	510	7	40	3	1	0.73	7	66	5100	17	55
322	13	40	18	521	10	40	3	1	0.45	6	83	4800	18	101
323	13	12	14	320	24	39	3	1	0.82	14	64	4000	13	98
324	12	9	12	323	17	51	2	3	0.00	6	33	4200	12	113
325	12	32	29	523	18	6	3	2	0.00	7	89	4900	24	122
326	14	25	16	531	6	1	5	1	0.65	22	62	3300	5	58
327	14	57	23	510	12	27	3	2	0.72	8	62	4000	26	56
328	13	5	9	510	21	49	2	3	0.36	7	11	3600	6	103
329	11	116	30	510	23	46	3	3	0.23	10	73	5200	0	86
330	13	7	8	510	15	48	3	1	0.77	9	100	4900	34	58
331	13	71	26	510	9	30	5	3	0.00	12	76	4000	4	113
332	12	5	9	521	14	27	3	1	0.00	6	44	3400	63	70
333	14	61	24	523	23	9	5	1	0.56	6	83	3200	42	146
334	13	84	27	591	22	14	3	3	0.00	12	85	3500	1	60
335	11	1	7	510	5	45	3	1	0.30	6	85	4400	4	130
336	14	4	7	593	31	39	3	1	0.09	19	100	4100	40	33
337	11	6	11	592	19	45	3	1	0.18	15	100	5000	0	93
338	13	10	9	510	27	65	3	1	0.00	14	66	5000	47	60

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Table 2 (continued)

STAND SUMMARY DATA FOR STANDS EXAMINED IN 1982

STAND	CUTSYS	ACRES	PLOTS	HABIT	ASPECT	SLOPE	PHY	PREP	SEVIDX	AGE	STOCK	ELEV	IBA	OBA
401	11	51	22	313	21	30	2	2		14		6200		
402	11	8	8	313	22	20	2	2		15		6900		
403	11	68	21	323	00	40	2	3		12		6800		
404	14	4	6	663	09	50	2	1		8		6500		
405	11	56	25	732	29	8	1	2		10		7000		
406	14	5	6	250	13	8	1	1		9		6400		
407	11	15	14	312	21	30	2	3		18		6600		
408	14	25	16	312	20	40	2	1		18		6600		
409	11	5	10	322	27	5	5	3		5		6000		
410	12	20	18	313	22	40	2	1		18		6500		
411	14	35	23	312	21	30	2	1		18		6600		
412	12	8	9	210	19	30	2	2		20		6500		
413	14	95	26	323	15	30	2	1		18		5800		
414	11	16	14	732	18	20	1	2		7		7200		
415	14	54	26	750	18	40	2	1		22		7400		
416	14	90	25	750	18	40	2	1		21		7400		
417	11	4	9	640	19	3	2	2		5		6500		
418	12	3	9	312	22	8	2	2		20		6100		
419	14	2	7	640	30	30	2	2		5		6600		
420	11	3	7	791	3	3	5	1		29		6200		
421	11	86	24	731	18	20	5	2		17		6200		
422	13	55	25	313	9	20	5	2		19		6700		
423	11	5	11	292	5	24	3	2		9		5900		
424	13	4	8	323	0	37	3	1		14		6600		
425	11	24	18	640	35	8	3	1		13		7100		
426	12	5	8	313	18	8	3	1		11		6000		
427	14	3	6	470	30	30	3	1		9		6000		
428	12	261	30	312	15	15	2	1		21		6800		
429	13	67	25	312	0	20	3	1		17		5600		
430	12	206	27	312	15	21	3	2		22		6600		
431	12	45	19	731	9	35	3	2		13		6300		

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Analysis of 1979-1981 Data

In our last Comprehensive Progress Report (Carlson and others 1982) we presented results of analyses concerning the influence of WSBW on stocking probability in several groups of habitat types. Also, we presented tentative models for predicting severity of WSBW attack--the foundation for a hazard rating system. We have not done and cannot do much more on either of those analyses until the 1982 data are ready for analysis. We did (1) develop models for vigor (5-year leader growth) based on the 1979-81 data, (2) complete analyses on the small tree study, and (3) complete a major literature review of the relationships of WSBW and SBW to stand conditions and the efficacy of past insecticidal practices in reducing WSBW populations.

VIGOR MODELS

Western spruce budworm defoliation of conifer regeneration could reduce the vigor of affected trees. We defined and measured vigor of conifer regeneration as cumulative 5-year leader growth referenced to the terminal bud of the year prior to measurement. Vigor was regressed against a number of variables. The multiple linear regression model originally tested was

$$\hat{Y} = a + b_1A + b_2H + b_3R + b_4S + b_5J + b_6C + b_7D + b_8P + b_9W + b_{10}O + b_{11}T + b_{12}F + b_{13}G + e$$

where:

$\hat{Y}$ = vigor (most recent 5-year height growth)
A = Age, years
H = Height, feet
R = Ratio of crown length to height
S = Tangent of slope
J = Slope * sin of aspect
C = Slope * cosin of aspect
D = Current WSBW damage, average code
P = Past WSBW damage, average code
W = Proportion shoots damaged by WSBW
O = Crown position of tree
T = Total basal area of overstory at plot
F = Dummy variable for no site preparation
G = Dummy variable for mechanical site preparation

This model included only data taken from established, subsequent conifer regeneration, seedlings that became established after the harvest cut was done. Furthermore, the model was run separately for Douglas-fir, larch, and pine in each of our six habitat type groups (appendix 2). Analysis of residual plots made necessary the transformation and retesting of certain variables.

Only tree height and age were important predictors in our model. A log transformation was necessary to stabilize variances of height, age, and vigor. Because of high intercorrelation between age and height, age was dropped from the analysis.

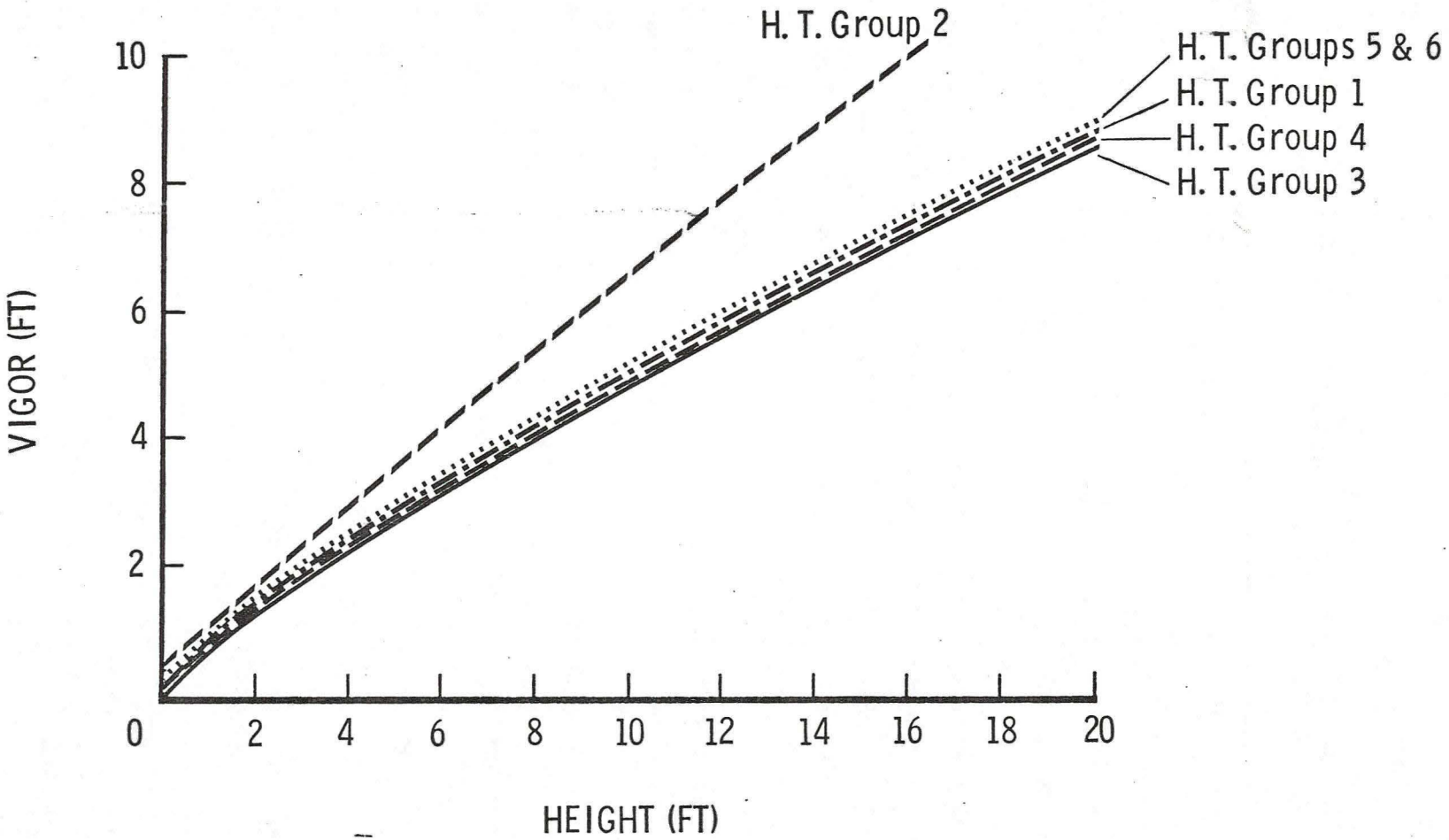
The variables representing WSBW defoliation on seedlings, D, P, and W, were not even remotely associated with reduced vigor of subsequent seedlings. Seldom did any of these variables represent defoliation exceeding 25 percent, very light injury. In the case of western larch for which it is known that WSBW severs terminals, the effect on vigor was, nevertheless, not significant, probably because of the strong transfer of apical dominance to subordinate laterals.

Douglas-fir in habitat group 2 (warm, moist Douglas-fir habitat types) appeared to be more vigorous than the others, especially at heights greater than 3 feet (fig. 3). Also, there appears to be strong species differences, as one might expect. Western larch and ponderosa pine both tended to be more vigorous than Douglas-fir.

SMALL TREE STUDY

Predation of WSBW larvae on small trees appears to be an important natural regulating factor. All field data on the small tree study have been collected and analyzed. Total remaining WSBW per tree at study termination, defined as the sum of remaining larvae, intact pupae, exuviae, and fragmented pupae, were converted to numbers/100 buds. The number of buds on a sample tree was not counted but was estimated by the following formula:

Figure 3.--Influence of habitat type on vigor (5-year leader growth) of Douglas-fir subsequent regeneration. Trees in habitat group 2, the warm, moist Douglas-fir habitats, grew faster than those in other groups. No detectable effect of WSBW on vigor was found in any of the groups.



$$\hat{Y} = 65.29 + 38.45^{*} X$$

where:

$\hat{Y}$ = number of buds

X = crown volume

This model was developed from surrogate data taken from other small trees in the sample stands.

Because variances between treatments were unequal, the "T" test for separate variance estimate was used to determine treatment significance.

The exclusion of ants and birds at Chamberlain Creek, where WSBW larval populations were moderate, favored development of WSBW to late instars and adults. On larch, birds and ants together significantly reduced WSBW counts, but on Douglas-fir the ants appeared most effective. At Pearson Creek, where WSBW was very light, ants and birds on larch significantly reduced insect counts but no effect was observed on Douglas-fir.

The amount of injury (defoliation) increased on larch and fir as insect numbers increased at both locations. Using only data from the "ants and birds excluded" treatment but from both locations, simple linear regression models were computed and the data were plotted (figs. 4 and 5). The increased scatter noted on the western larch plot is due to the large number of feeding sites available; all long shoots and dwarf shoots were used as the basis, whereas for Douglas-fir only the current shoots are considered suitable feeding sites.

This exploratory study of predation of WSBW larvae on small trees strongly suggests that predators such as birds and ants, especially ants, exert a significant controlling influence on the budworm. This partially explains why we have not observed significant WSBW damage to small trees in the harvested units we have studied.

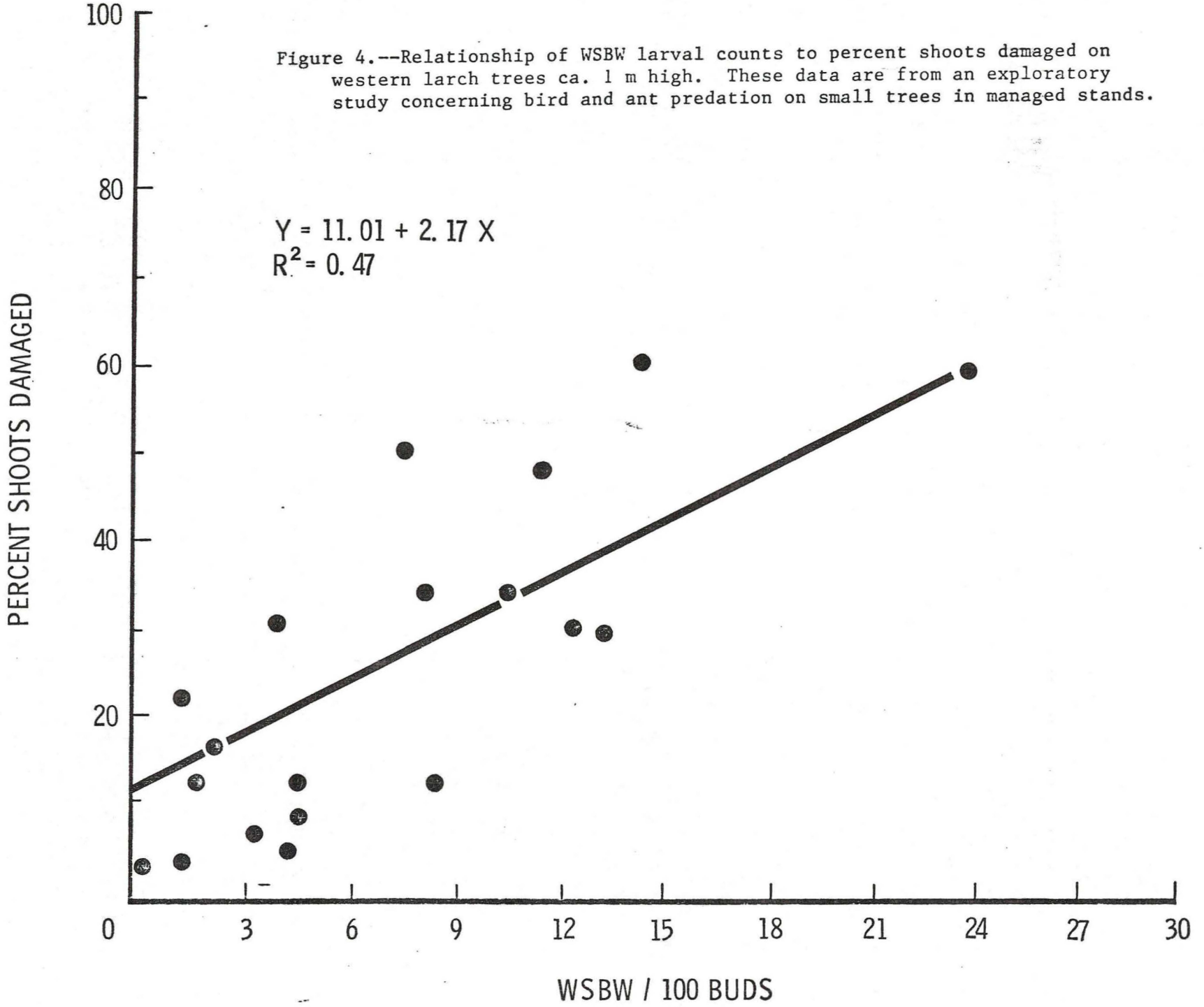


Figure 4.--Relationship of WSBW larval counts to percent shoots damaged on western larch trees ca. 1 m high. These data are from an exploratory study concerning bird and ant predation on small trees in managed stands.

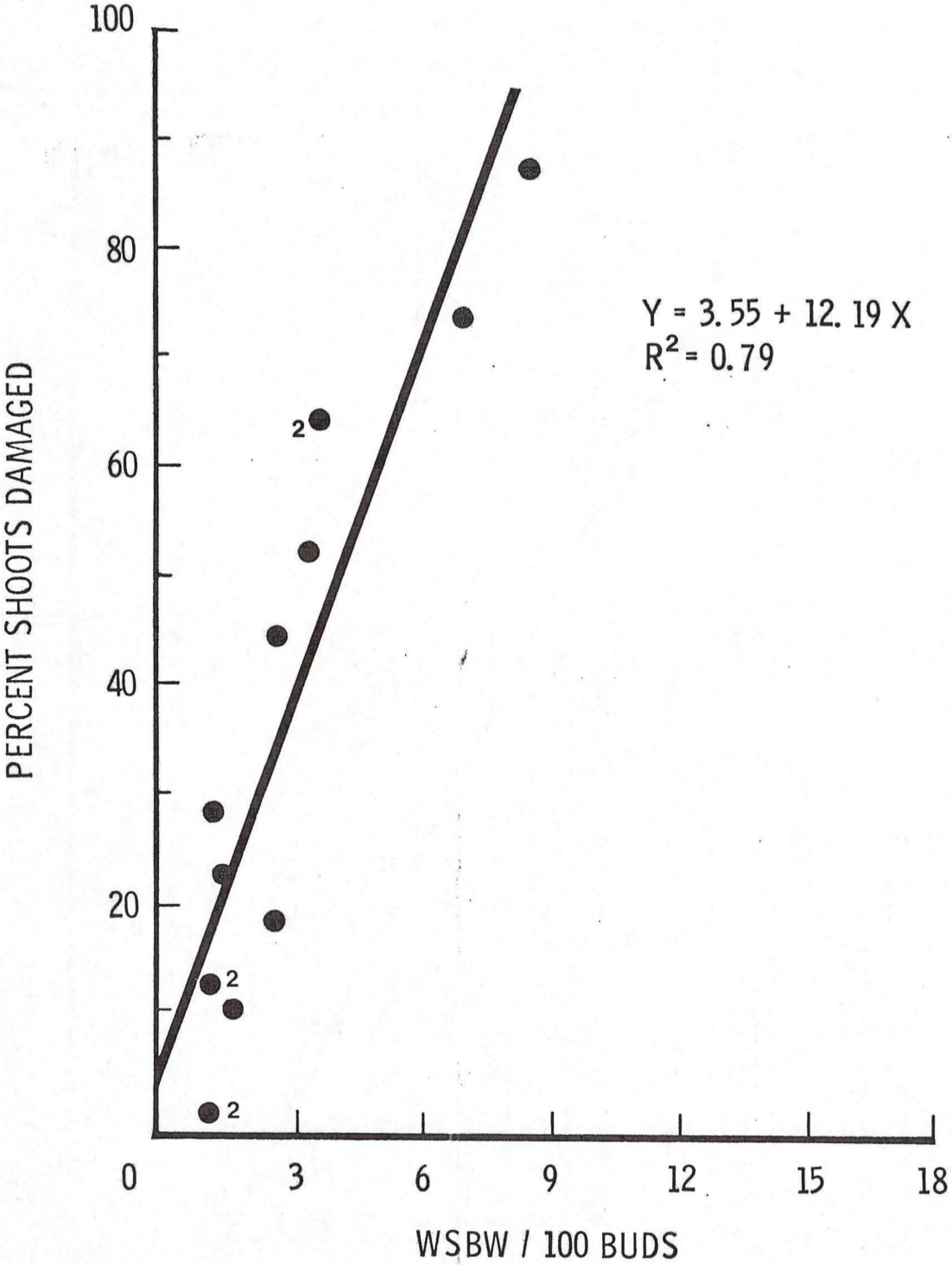


Figure 5.--Relationship of WSBW larval counts to percent shoots damaged on Douglas-fir trees ca. 1 m high. About six WSBW larvae can cause some defoliation on 50 percent of the new shoots. This usually does not occur because predators such as birds and ants reduce larval numbers to low levels before the larvae reach the fifth and sixth instars.

LITERATURE REVIEW

We conducted and published in 1982 a rather extensive literature search concerning management strategies for the WSBW. The paper "The Western Spruce Budworm in Northern Rocky Mountain Forests: A Review of Ecology, Past Insecticidal Treatments, and Silvicultural Practices" by C. E. Carlson, D. G. Fellin, and W. C. Schmidt summarizes the ecological adaptations of WSBW to Northern Rocky Mountain forests. A concise history and appraisal of past insecticide applications and their apparent lack of success is described relative to the strategies involved. Based partially on the small number of western studies and the more numerous eastern studies, relationships of WSBW to stand conditions--species composition, density, habitat type, and intrinsic site conditions--are described. In the final section on silvicultural treatment it is concluded that the surest hope for reducing WSBW damage to managed stands will be through sound, intensive silvicultural treatments. Insecticides may be effective on very high value areas such as seed production areas or campgrounds where the expense of multiple insecticide applications can be tolerated. The manuscript cites 144 published and unpublished papers.

Status of 1982 Data

Fieldwork proposed for 1982 is complete. We reexamined the seven intensive stands and collected appropriate data from 31 extensive stands east of the Continental Divide in Montana. We could not collect data from 48 stands because (1) stands meeting all our criteria were not available and (2) distances between candidate stands were much greater than in western Montana and more crew time was spent in travel status. Nevertheless, we did obtain a good representation of data from a variety of stand types in the Douglas-fir and subalpine fir habitat types east of the Continental Divide.

All 1982 data, including regeneration data, outside (adjacent stand) data, and increment core data have been keypunched and input to electronic data files. This amounts to about 12,000 records. We are now screening and editing the data and will begin analysis in January 1983.

CONCLUSIONS AND RECOMMENDATIONS

Our analyses are continuing and conclusions now must be considered tentative. The first four items are based on the progress report for April 1, 1981-March 31, 1982. The last three are based on the text of the current report. Our data indicate that:

1. Probability of stocking with natural regeneration is reduced in dry Douglas-fir, dry subalpine fir, and moderate subalpine fir habitat type groups. Apparently this is due to reduced cone and seed supply in habitats that regenerate primarily to WSBW host species.

2. Vulnerability of stands to WSBW attack is somewhat predictable. Dry Douglas-fir habitats on steeper slopes with a predominance of the stand in host basal area are most vulnerable; wetter, colder habitats are least vulnerable.

3. WSBW spring dispersal of Stage II larvae does not appear to be related to local stand conditions. Dispersal is relatively uniform and equal between and within cut and uncut stands.

4. Seedling defoliation by WSBW is only weakly dependent on larval dispersal. Defoliation of seedlings in previously cut stands generally is quite low, irrespective of the number of larvae reaching the target area or the defoliation intensity in the adjacent stands.

5. Vigor, or the most recent 5-year height growth, of WSBW-susceptible subsequent conifer seedlings and saplings 1 to 20 years old is not detectably influenced by WSBW feeding. These small trees in well-managed stands seldom are defoliated more than 25 percent, and this light defoliation apparently is not significant in reducing apical growth.

6. Vulnerability of small trees to WSBW in managed stands is low partly because the WSBW larvae appear to be quite vulnerable to predation by ants and birds. Also, the smaller target area offered by small trees to dispersing Stage II larvae results in greater dispersal loss.

7. Available literature--both eastern and western--indicates that long-term effective management of WSBW will, in large part, depend on quality silvicultural treatment in managed stands.

Our recommendations for silvicultural treatment to reduce stand susceptibility and vulnerability to WSBW have not changed since our 1981 and 1982 progress reports to CANUSA. Looking ahead, and based on data from past harvest cuts, it certainly appears possible to utilize silvicultural techniques to reduce the impact of WSBW on establishment and growth of managed conifer stands. The following suggestions are merely a beginning look at what we can do. It is first understood that in any harvest cut (or others, such as thinning, etc.), the basic ecological criteria for seedling establishment and growth, exclusive of WSBW considerations, must first be met. Within those restrictions, the following ideas appear valid:

1. Reduce the ratio of host:nonhost basal area. In partial cuts, favor the nonhost species.

2. Remove residual host overstory from partial cuts no later than 10 years following establishment of regeneration.

3. For partial cuts, minimize the residual host basal area left either for seed source or shelter.

4. Create a "buffer" by reducing basal area of host species in adjacent stand within 100 meters of the boundary of the adjacent stand.

5. Make cutting units as large as possible commensurate with other management restrictions.

6. When planting, prescribe a good mix of species, but no more than one-third host seedlings.

7. During stand development, maintain the minimum number of seedlings-per-acre/basal area relative to other management objectives, and maintain a minimum ratio of host:nonhost growing stock (1:3 or 1:4).

These actions, if and when invoked over large enough land bases (subcompartment, for example), may influence adult and larval WSBW dispersal, will limit population size, and will significantly reduce present and current WSBW impact on stands managed for fiber production.

WORK REMAINING ON STUDY

This study was originally designed to study WSBW relationships in four silvicultural systems over the three major forest climax series found in western Montana. We were funded for FY 1982 to collect similar data in subalpine fir and Douglas-fir stands in eastern Montana and this work has been done.

Fiscal year 1983, the final year of CANUSA funding for this study, will be devoted primarily to data analyses and writing. Analysis of the data has been continuing since 1980. A composite analysis which will include all data will now be done. Hypotheses stated in the methods section will be tested and new ideas which we may have overlooked will be considered. A final Comprehensive Report will be prepared before the end of FY 1983 and will include all analyses, models, and results pertinent to this study.

COOPERATION AND COORDINATION

We continue to cooperate with the Moscow Forestry Sciences Laboratory, with Region 1 Forest Pest Management and Region 1 Timber Management, and with the Bureau of Land Management and Bureau of Indian Affairs. Dennis Ferguson of Moscow, and Bill Wulf of Region 1, continue to be particularly cooperative.

PROBLEMS ENCOUNTERED

No significant problems were encountered. Our research is progressing on schedule.

MANUSCRIPTS OR REPORTS PREPARED OR PLANNED

Manuscripts Published

Carlson, C. E., and W. McCaughey.
1982. Radial increment analysis to index past western spruce budworm activity in western Montana. USDA For. Serv. Res. Pap. INT-291. Ogden, UT.

Manuscripts in Press

Carlson, C. E., D. G. Fellin, and W. C. Schmidt.
1983. The western spruce budworm in Northern Rocky Mountain forests: A review of ecology, past insecticidal treatments, and silvicultural practices. Proc. Symp. Management of second-growth forests: the state of knowledge and research needs. Univ. of Mont., Missoula.

Manuscripts in Preparation

Carlson, C. E., L. Theroux, W. McCaughey, and W. Schmidt.
1983. Influence of western spruce budworm on stocking probabilities in western Montana.

Carlson, C. E., and L. J. Theroux.
1983. Factors associated with severity of western spruce budworm attack.

Carlson, C. E., L. J. Theroux, and W. C. Schmidt.
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Fellin, D. G.
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Fellin, D. G., R. C. Shearer, and C. E. Carlson.
1983. The western spruce budworm in the Northern Rocky Mountains. Western Wildlands.

Schmidt, W. C., D. G. Fellin, and C. E. Carlson.
1983. Alternatives to the use of chemical insecticides in management of western spruce budworm. Western Wildlands.

Papers Presented

Carlson, C. E., and L. Theroux.
1982. Predicting intensity of western spruce budworm radial growth reduction in western Montana forests. Abstract, 55th Ann. Northwest Scientific Association, March 1982.

Carlson, C. E.
1982. Current developments in research concerning budworm-stand relationships in western Montana. Panel presentation, 33rd Western International Forest Work Conference, Missoula, MT.

Carlson, C. E., D. G. Fellin, and W. C. Schmidt.
1982. The western spruce budworm in Northern Rocky Mountain forests: A review of ecology, past insecticidal treatments, and silvicultural practices. Proc. Symp. Management of second-growth forests: the state of knowledge and research needs. May 14, 1982. Univ. of Mont., Missoula.

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Carlson, C. E., and W. McCaughey.

1982. Indexing western spruce budworm activity through radial increment analysis. USDA For. Serv. Res. Pap. INT-291. Intermountain For. and Range Exp. Stn., Ogden, Utah.

Carlson, C. E., L. J. Theroux, and W. W. McCaughey.

1982. The influence of silvicultural practices on the susceptibility and vulnerability of Northern Rocky Mountain forests to the western spruce budworm. Comprehensive Prog. Rep. April 1, 1981-March 31, 1982. USDA For. Serv., Intermountain For. and Range Exp. Stn., Missoula, Mont. 55 p.

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APPENDIXES

APPENDIX 1

WSBW LOSSES ON SMALL TREES: EFFECTS OF BIRD AND ANT PREDATION

Work Plan
Prepared by:

Clinton E. Carlson
June 25, 1982

Western spruce budworm seldom mature to adults on small trees less than 3 meters high. This is especially apparent in young, even aged managed conifer stands regenerated through an appropriate silvicultural system. This study is an exploratory effort to determine whether birds and ants cause significant mortality to WSBW larvae on small trees.

Experimental Design.

Four treatments will be replicated ten times on representatives of two conifer species in two different stands. The treatments are:

1. Control
2. Exclude ants
3. Exclude birds
4. Exclude ants and birds.

The conifers, Douglas-fir (Pseudotsuga menziesii) and western larch (Larix occidentalis), are components of even-aged regeneration (about 12 years) resulting from seed tree cuts in Chamberlain Creek and Pearson Creek about 50 miles northeast of Missoula, MT.

Sample trees will be limited to trees between 0.6 - 1.0 meter high and treatments will be randomly assigned to trees. Total height, length of live crown, and crown width will be recorded for each sample tree. Also, the regeneration density (considering the tree as the center of a 1/300 acre plot) will be recorded at each sample tree.

Bird-exclusion cages about 1 x 1 x .75 meters will be constructed of plastic pipe and netting. Tanglefoot applied at tree bases will exclude ants. After the treatments have been invoked, two WSBW pupae will be attached to each tree. During late summer, after adults have emerged, the number of pupal cases on each tree will be counted. These will be identified and recorded as remains of experimental pupae (pupae originally placed on the tree) or natural pupae (pupae resulting from larvae on the tree prior to treatment). Percent defoliation of small trees will be recorded according to methods of Carlson and others (1982).[1/]

[1/] Carlson, C.E., L.J. Theroux, and W.W. McCaughey. 1982. Comprehensive CANUSA Progress Report for 1982.

Logistics and Cooperation

According to this design, 80 cages 1 x 1 x .75 meter will be needed for bird exclusion. Sample trees will number 160. At 2 pupae per tree, 320 pupae will be required. Our field personnel will select and measure sample trees, help install the treatments, and aid in final data collection. Bob Campbell and his field team will build the cages, help install the treatments, and aid in final data collection. All data will be recorded on the attached field form. Analysis of data and publication of results will be done jointly with Bob Campbell.

WSBW LOSSES ON SMALL TREES 1982

Location _____

Recorder _____

Stand	Treatment	Tree #	Species	TPA	Tree height	Crown length	Crown width	Experimental Pupae		Natural Pupae		Western Larch							D.F.
								Placed	Emerged	Non-emerged	Emerged	% fascicles damaged	10-Lateral				Terminal damage	Percent Defoliation	
													No damage	Needle feeding	Shoot mining	Severed shoots			
1	2	3 4	5 6	7 8	9 10	11 12	13 14	15 16	17 18	19 20	21 22	23 24	25 26	27 28	29 30	31 32	33	34 35	36

APPENDIX 2

Habitat Type Groupings for 1979, 1980, and 1981 data[1]

Habitat code	Type name[2]
GROUP 1 (Dry Douglas-fir)	
10	Scree
210	PSME/AGSP
230	PSME/FESC
261	PSME/PHMA-PHMA
262	PSME/PHMA-CARU
311	PSME/SYAL-AGSP
312	PSME/SYAL-CARU
313	PSME/SYAL-SYAL
360	PSME/JUCO
350	PSME/ARUV
Total types 10	Total plots 592
GROUP 2 (Moist Douglas-fir)	
250	PSME/VACA
281	PSME/VAGL-VAGL
282	PSME/VAGL-ARUV
283	PSME/VAGL-XETE
291	PSME/LIBO-SYAL
292	PSME/LIBO-CARU
293	PSME/LIBO-VAGL
321	PSME/CARU-AGSP
322	PSME/CARU-ARUV
323	PSME/CARU-CARU
324	PSME/CARU-PIPO
330	PSME/CAGE
340	PSME/SPBE
Total types 13	Total plots 450
GROUP 3 (Dry suablpine fir)	
690	ABLA/XETE
691	ABLA/XETE-VAGL
692	ABLA/XETE-VASC
792	ABLA/CAGE-PSME
Total types 4	Total plots 353
GROUP 4 (Warm & moist subalpine fir, grand fir, and cedar	
440	PICEA/GATR
510	ABGR/XETE
520	ABGR/CLUN
521	ABGR/CLUN-CLUN
522	ABGR/CLUN-ARNU
523	ABGR/CLUN-XETE
530	THPL.CLUN
531	THPL/CLUN-CLUN
532	THPL/CLUN-ARNU
533	THPL/CLUN-MEFE
591	ABGR/LIBO-LIBO
592	ABGR/LIBO-XETE
571	TSHE/CLUN-CLUN
572	TSHE/CLUN-ARNU
621	ABLE/CLUN-CLUN
622	ABLA/CLUN-ARNU
623	ABLA/CLUN-VACA
624	ABLA/CLUN-XETE
625	ABLA/CLUN-MEFE
630	ABLA/GATR
640	ABLA/VACA
Total types 21	Total plots 726
GROUP 5 (Moderate subalpine fir)	
653	ABLA/GATR
661	ABLA/LIBO-LIBO
662	ABLA/LIBO-XETE
663	ABLA/LIBO-VASC
720	ABLA/VAGL
731	ABLA/VASC-CARU
750	ABLA-CARU
Total types 7	Total plots 173
GROUP 6	
670	ABLA/MEFE
680	TSME/MEFE
740	ABLA/ALSI
Total types 3	Total plots 183

[1]Partially based on personal communication with Dr. Robert Pfister in 1980.

[2]From "Forest Habitat Types of Montana" by Robert Pfister and others. INT GTR-34, 1977.